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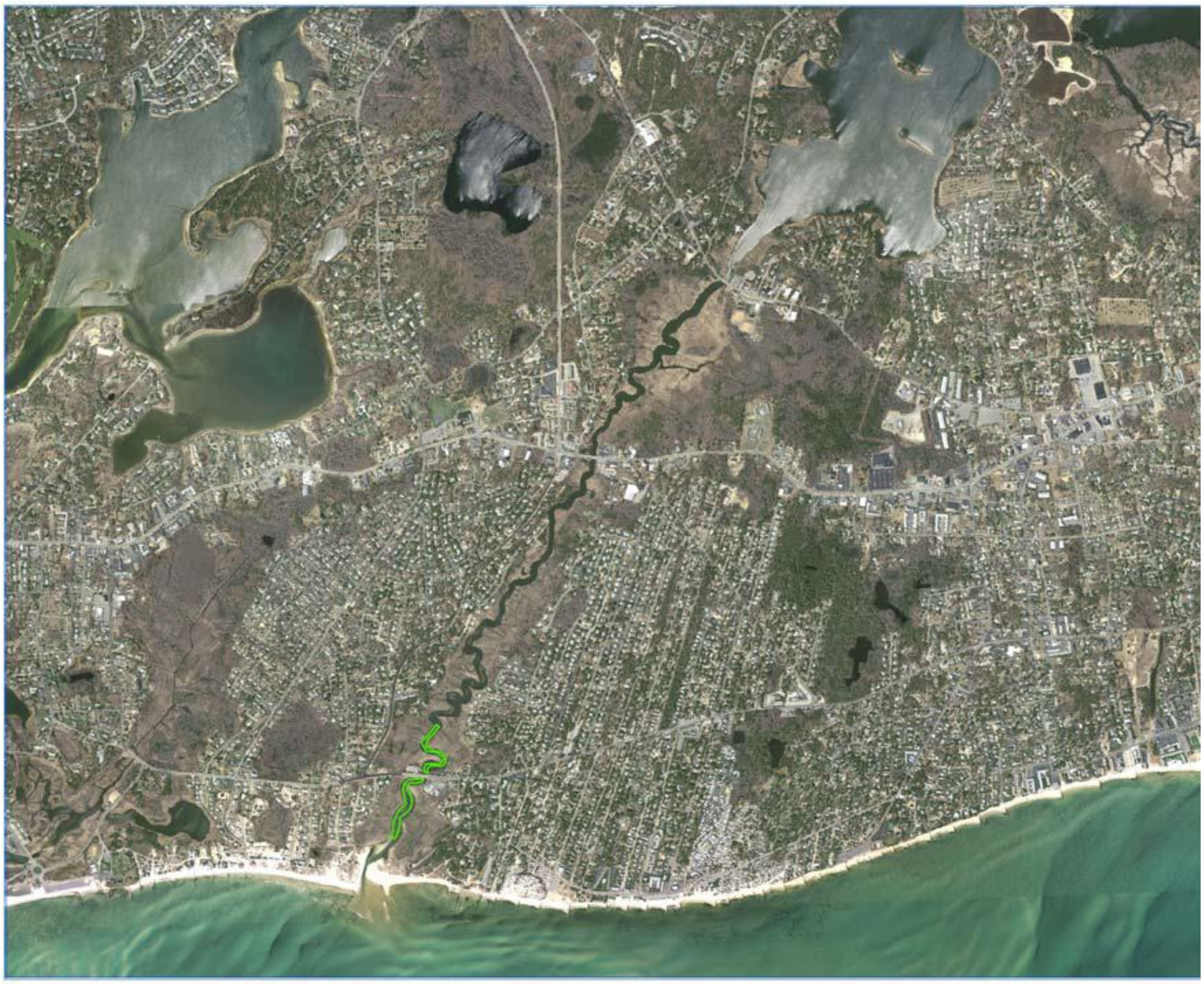
Swan Pond River Estuarine System
Total Maximum Daily Load
For Total Nitrogen
CN 393.0



COMMONWEALTH OF MASSACHUSETTS
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November 2016

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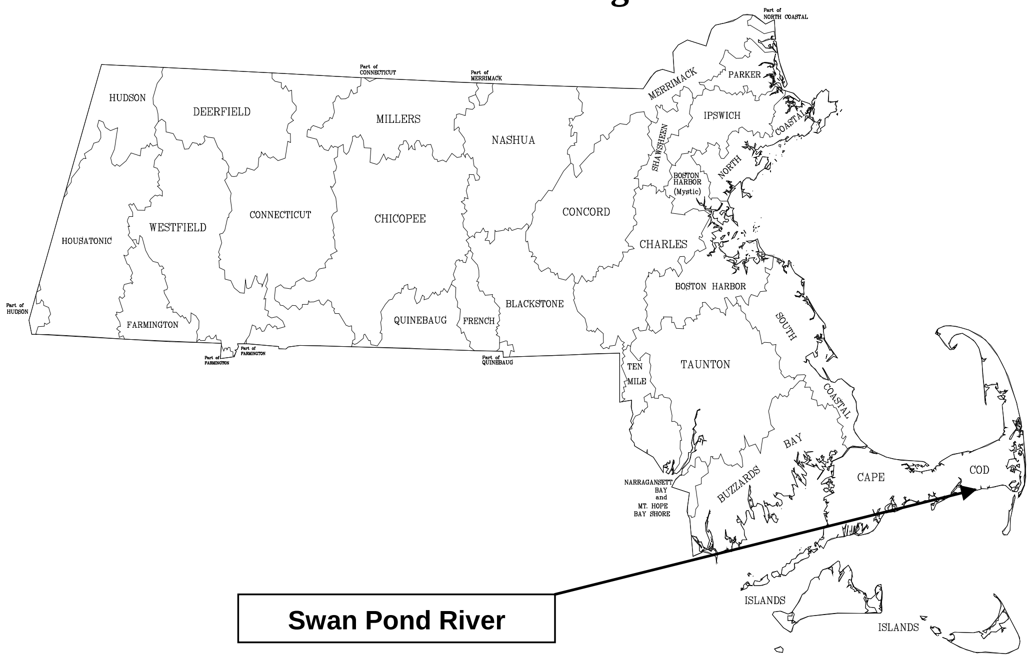


Key Feature: Total Nitrogen TMDL for the Swan Pond River Estuarine System

Location: US Environmental Protection Agency (EPA) Region 1, Dennis, MA

Land Type: New England Coastal

303d Listing: The Swan Pond River (MA 96-14) is impaired and listed in Category 5 of the 2014 Integrated List of Waters as impaired for aquatic life (loss of eelgrass and benthic habitat) and shellfishing (fecal coliform). The Swan Pond River estuarine system was found to be impaired for nutrients during the MEP study. Swan Pond will be listed as impaired for nutrients in a future List of Waters.

Data Sources: University of Massachusetts – Dartmouth/School for Marine Science and Technology, US Geological Survey, Applied Coastal Research and Engineering, Inc., Town of Dennis

Data Mechanism: Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model

Monitoring Plan: Town of Dennis, Dennis Water District Water Quality Monitoring Program (with technical assistance from SMAST)

Control Measures: Sewering, Stormwater Management, Attenuation by Impoundments and Wetlands, Fertilizer Use By-laws

Executive Summary

Problem Statement

Excessive nitrogen (N) originating from a range of sources has added to the impairment of the environmental quality of the Swan Pond River estuarine system. Excessive N is indicated by:

- Undesirable increases in macro algae
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Significant loss of eelgrass habitat
- Periodic algae blooms

With proper management of N inputs these trends can be reversed. Without proper management more severe problems might develop, including:

- Periodic fish kills
- Unpleasant odors and scum
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities

Coastal communities rely on clean, productive and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings could result in an overabundance of macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of the Swan Pond River estuarine system will be greatly reduced.

Sources of Nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
    - Natural background
    - Septic Systems
    - Runoff
    - Fertilizers
    - Agricultural activities
    - Landfills
    - Wastewater treatment facilities;
- Atmospheric deposition;
- Nutrient-rich bottom sediments in the embayments.

Figure ES-A and Figure ES-B illustrate the percent contribution of all the sources of N and the controllable N sources to the estuary system, respectfully. Values are based on Table IV-3 and Figure IV-5 from the Massachusetts Estuaries Project (MEP) Swan Pond River Embayment System Technical Report. As evident, most of the present *controllable* load to this system comes from septic systems.

Figure ES-A: Percent Contributions of All Nitrogen Sources to the Swan Pond River Estuarine System

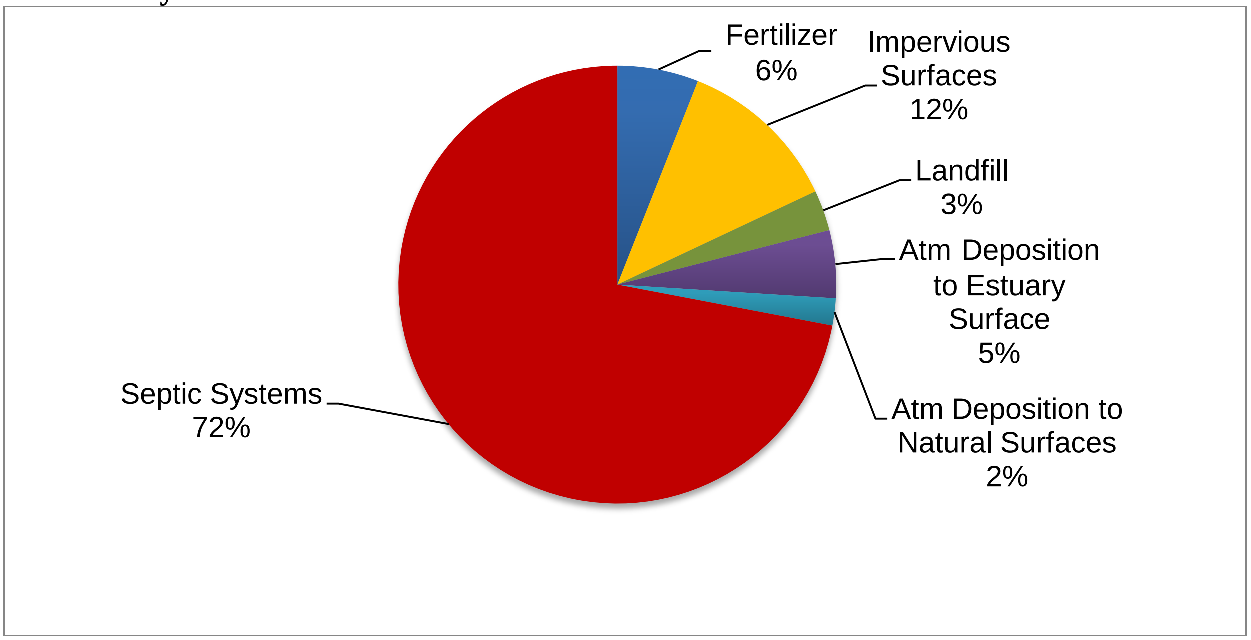
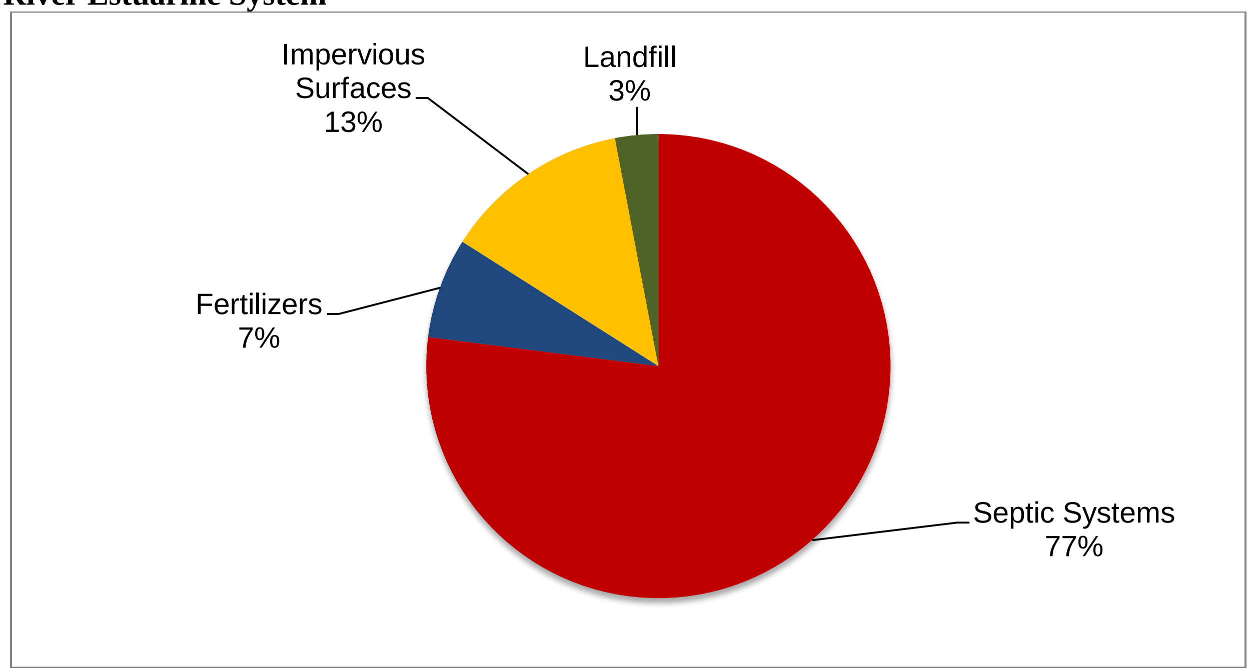


Figure ES-B: Percent Contributions of Controllable Nitrogen Sources to the Swan Pond River Estuarine System



Target Threshold N Concentrations and Loadings

The Swan Pond River and Swan Pond lie entirely within the Town of Dennis on Cape Cod, Massachusetts. The watershed of this system is predominately in Dennis but very small portions are shared between the Towns of Harwich and Brewster. The total N loading (the quantity of N) to this system is 46 kg N/day from the combined three major subwatersheds (Swan Pond, Swan Pond River North and Swan Pond River South). The resultant concentrations of N ranged from 0.449-1.547 mg/L in the entire system (range of annual means collected from 7 stations during 2005-2010 as reported in Table VI-1 of the MEP Technical Report, and included in Appendix A of this report).

In order to restore and protect this estuarine system, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below those that cause the observed environmental impacts. This N concentration will be referred to as the *target threshold N concentration*. The Massachusetts Estuaries Project (MEP) has determined that by achieving a total N concentration of 0.40 mg/L near sentinel station SWP-2 in the middle of the lower reach of the Swan Pond River (see Figure 5), water and habitat quality will be restored in these systems. The mechanism for achieving the target threshold N concentrations is to reduce the N loadings to the watershed of the estuarine system. Based on the MEP sampling and modeling analyses and their Technical Report, the MEP study has determined that the Total Maximum Daily Load (TMDL) of N that will meet the target threshold N concentration of 0.40 mg/L is 13.1 kg N/day (note: this number is slightly different from the technical report, as negative benthic flux was set to zero in the TMDL). To meet the TMDL this report suggests that a 77% reduction of the total watershed nitrogen load for the entire system will be required.

This document presents the TMDL for the Swan Pond River Estuarine System and suggests possible options to Dennis as well as the watershed towns of Harwich and Brewster on how to reduce the N loadings to meet the recommended TMDL and protect the waters of this embayment system.

Implementation

The primary goal of TMDL implementation will be lowering the concentrations of N by targeting loadings from on-site subsurface wastewater disposal (septic) systems. The MEP Technical Report for the Swan Pond River Estuarine System indicated that by reducing septic loads by 100% throughout the watershed, the target thresholds can be met. However, there may be other loading reduction scenarios that could achieve the target threshold N concentrations. These options would require additional modeling to verify their effectiveness.

Local officials can explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). Implementing best management practices (BMPs) to reduce N loadings from fertilizers and runoff where possible will also help to lower the total N load to the system. Methods for reducing N loadings from these sources are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies" which is available on the MassDEP website http://www.mass.gov/eea/agencies/massdep/water/watersheds/coastal-resources-and-estuaries.html The appropriateness of any of the alternatives will depend on local conditions and will have to be determined on a case-by-case basis using an adaptive management approach. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208.

Finally, growth within the communities of Dennis, Harwich, and Brewster that would exacerbate the problems associated with N loadings should be guided by considerations of water quality-associated impacts.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters that are not meeting water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings of these pollutants of concern, taking into consideration all contributing sources to that water body, while allowing the system to meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernible, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources that will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The MassDEP will work with the municipalities to develop specific implementation strategies to reduce N loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Swan Pond River Estuarine System the pollutant of concern for these TMDLs (based on documentation of eutrophication) is the nutrient nitrogen. Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration increase so does the amount of plant matter. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton which impairs the healthy ecology of the affected water bodies.

The TMDLs for total N for the Swan Pond River Estuarine System are based primarily on data collected, compiled and analyzed by University of Massachusetts Dartmouth's School of Marine Science and Technology (SMAST) Coastal Systems Program and the town of Dennis as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 2005 through 2010, a period which will be referred to as the "present conditions" in the TMDL report since it contains the most recent data available. The accompanying MEP Technical Report can be found at http://www.mass.gov/eea/agencies/massdep/water/watersheds/the-massachusetts-estuaries-project-and-reports.html. The MEP Technical Report presents the results of the analyses of the coastal embayment systems using the MEP Linked Watershed-Embayment N Management Model (Linked Model) (Howes *et. al*, 2012).

The analyses were performed to assist the watershed community with making decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open-space and harbor maintenance programs. A critical element of this approach is the assessments of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements and benthic community structure that was conducted on this embayment. These assessments served as the basis for generating a total N loading threshold for use as a goal for watershed N management. The TMDLs are based on the site specific total N threshold generated for this estuarine system. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision-making process for the watershed communities of Dennis, Harwich, and Brewster.

Description of Water Bodies and Priority Ranking

The Swan Pond River Estuarine System is a complex estuary located almost entirely within the Town of Dennis on Cape Cod. Small portions of the eastern edge of the watershed also lie within Harwich and Brewster(See Figure 1).The estuarine system is comprised of a almost 3 km meandering tidal river (Swan Pond River) connecting a large, but rather shallow kettle pond (Swan Pond) to Nantucket Sound. The Swan Pond River is functionally divided into an upper and lower river, falling north and south of the Route 28 bridge, respectively. The barrier beach around the inlet was formed from marine sands and gravel deposited by shoreline coastal process, as sea level rose (See Figure 2). The inlet is partially armored by a jetty on the western shore and must be dredged periodically to remove accumulated sand and to maximize tidal flushing within the estuary. The upper reach of the river and lower region of Swan Pond presently support significant wetland resources. Swan Pond is generally the same depth as Swan Pond River, both only 1.0 to 1.5 meters deep. The estuary system supports a diverse range of habitats, including the main tidal portion of Swan Pond which operates as a tidal river with extensive salt marsh along most of the shoreline. In fact, salt marsh dominates the banks of both the river and pond, supporting some of the most significant salt marsh resources in this area of Cape Cod. The embayment system is located within highly permeable sands and gravel outwash therefore stormwater runoff is typically low. Groundwater seepage is the major source of freshwater into the system, with only a small source of surface fresh water entering into Swan Pond via Hydaway Creek.

The primary ecological threat to the Swan Pond River Estuary System as a coastal resource is degradation resulting from nutrient enrichment. Loading of the critical eutrophying nutrient, nitrogen, to the Swan Pond River estuarine system has impaired its animal and plant habitats and resulted in ecological changes and lost marine resources. Nitrogen related habitat impairment within the Swan Pond River Estuary shows a gradient of high to low moving from the upper basin of Swan Pond to the tidal inlet.

Nitrogen enrichment occurs through two primary mechanisms, 1) high rates of nitrogen entering from the surrounding watershed and/or 2) low rates of flushing due to "restricted" tidal exchange with the low nitrogen waters of Nantucket Sound. Because of its structure, the Swan Pond River system is more susceptible to nitrogen enrichment than most estuaries in the region. This is because of the combined effect of the long meandering river and the large area of Swan Pond, which results in a tidal range of about 1 foot compared to 3 feet at the inlet. This creates a relatively low exchange of Swan Pond waters during each tidal cycle and allows for a greater buildup of nitrogen levels making the Pond more sensitive than if the system had a shorter river and larger tide range in the pond.

The nitrogen loading to the Swan Pond River estuary, like almost all embayments in southeastern Massachusetts, is primarily from on-site disposal of residential (and some commercial) wastewater. The Town of Dennis, like most of Cape Cod, has seen rapid growth over the past five decades and does not have a centralized wastewater treatment system or decentralized facilities that remove nitrogen. As such, none of the developed areas in the Swan Pond River watershed are connected to any municipal sewerage system and wastewater treatment and disposal is primarily through privately maintained on-site septic systems. As present and future increased levels of nutrients impact the coastal embayments in the Town of Dennis, water quality degradation will increase, with additional impairment and loss of environmental resources, as evidenced by the recent macroalgal blooms within Swan Pond.

As a result of its unique hydrodynamics and relatively high watershed nitrogen inputs, this estuarine system is presently one of the most nitrogen enriched estuaries on Cape Cod. Consequently, nitrogen management of the three primary sub-embayments to the Swan Pond River system must be for restoration, not protection or maintenance of existing conditions.

In the 2014 Integrated List of Waters, Swan Pond River is listed as impaired for nutrients and requires a TMDL (MassDEP, 2016). A pathogen TMDL has been prepared for the Swan Pond River to address bacteria impairment and so this segment is currently listed as a Category 4a Water (Table 1). Although already listed for 'estaurine bioassessments', Swan Pond will also be listed as impaired for nutrients in a future Integrated List of Waters.

Table 1: Swan Pond River Estuarine System Waterbodies in the MassDEP 2014 Integrated List of Waters

Name	MassDEP Segment ID	Description	Size	Category	Impairment Cause	EPA TMDL Number
Swan Pond River	MA96-14	Headwaters, outlet Swan Pond, Dennis to confluence with Nantucket Sound, Dennis.	0.04 square miles	5 (TMDL required)	Estaurine Bioassessments	
				4a (TMDL completed)	Fecal Coliform	36771

Figure 1: Watershed Delineations for the Swan Pond River Estuarine System

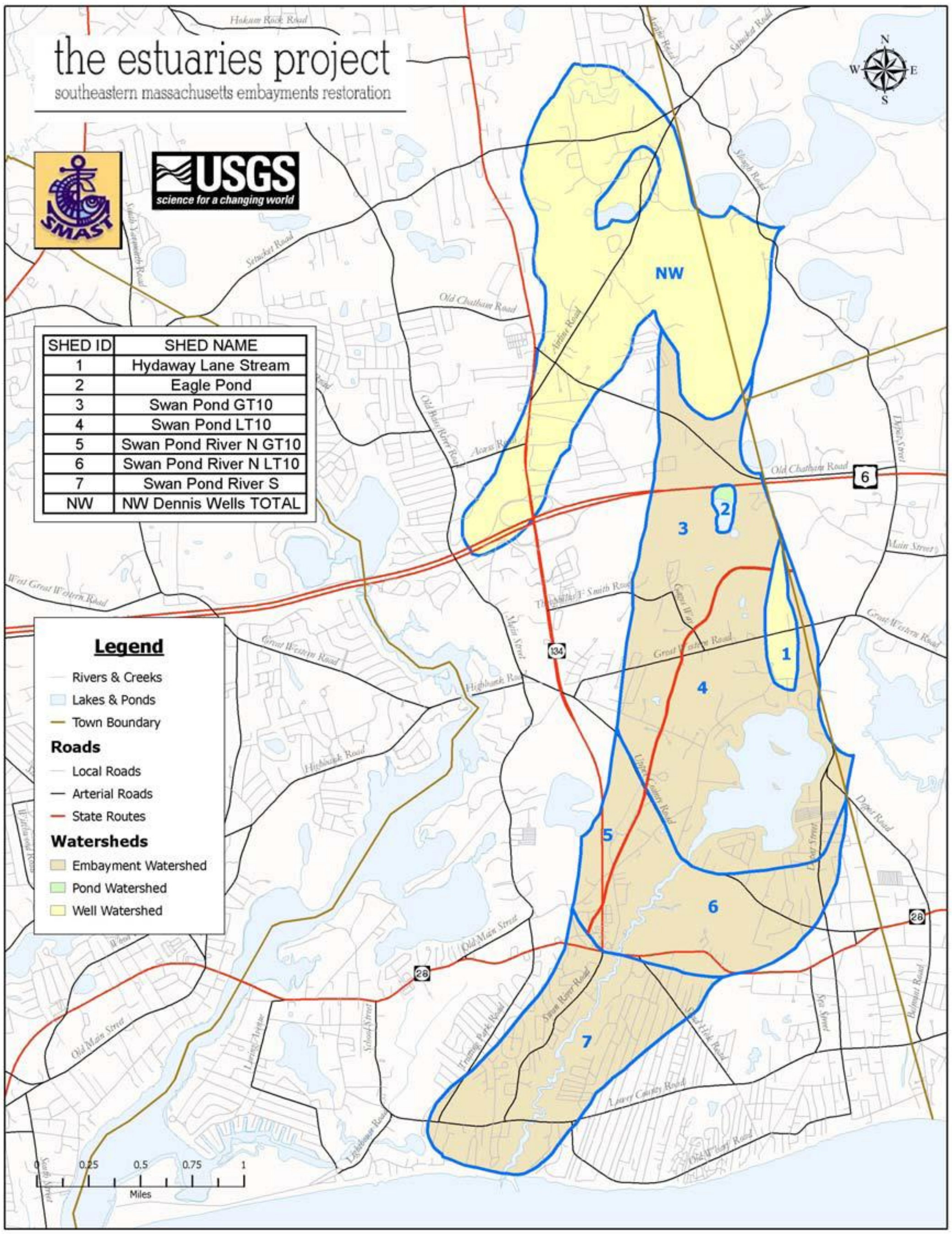


Figure 2: Map of the Swan Pond River Estuarine System
(from United States Geological Survey maps)

A majority of the information presented here is drawn from the MEP Technical Report (Howes *et. al*, 2012). A complete description of the embayment system is presented in Chapters I, III and IV of this report. Chapters VI and VII of the MEP Technical Report provide assessment data that show that the Swan Pond River Estuarine System is impaired because of nutrients, low dissolved oxygen levels, elevated chlorophyll *a* levels, and degraded eelgrass and benthic fauna habitat. Table 2 lists the MEP study impaired parameters. Swan Pond will be listed as impaired for nutrients in a future Massachusetts Integrated List of Waters.

Table 2: Impaired Waterbodies of the Swan Pond River Estuarine System*

Name	Segment ID	Description	Impaired Parameter
Swan Pond River	MA96-14	Headwaters, outlet Swan Pond, Dennis to confluence with Nantucket Sound, Dennis. (0.04 square miles)	Nutrients, DO Level, Chlorophyll *a*, Benthic Fauna, Eelgrass, Macroalgae, **Pathogens
Swan Pond	MA96-111_2018	Dennis	Nutrients, DO Level, Chlorophyll *a*, Benthic Fauna, Eelgrass, Macroalgae

* SMAST impaired parameter as a result of the MEP study.
** MassDEP impaired parameter (MassDEP 2015)

Priority Ranking

The embayment addressed by this document have been determined to be "high priority" based on three significant factors: (1) the initiative that the town of Dennis has taken to assess the conditions of the entire embayment system; (2) the commitment made by the town to restore the Swan Pond River estuarine system; and (3) the extent of impairment in the Swan Pond River estuarine system. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems and limits on the use of water resources. Observations are summarized in the Problem Assessment section below and detailed in Chapter VII, Assessment of Embayment Nutrient Related Ecological Health, of the MEP Technical Report.

Description of Hydrodynamics of Embayment System

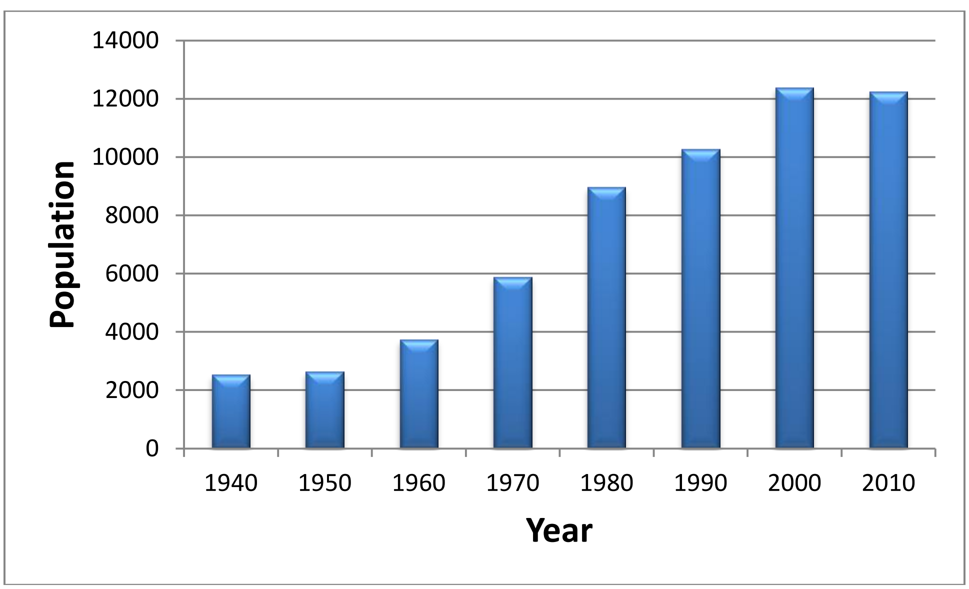
The MEP project has evaluated the tidal circulation and flushing characteristics of this embayment system using both direct measurements and the RMA-2 model, a well established model for estuaries. Using direct measurement of the tides at seven locations in the embayment system, Howes *et.al* (2012) observed the tide range to decrease from a mean tide range in Nantucket Sound of 3.5 feet to 0.6 feet in Swan Pond due to frictional losses along the length of the Swan River. The loss of amplitude with distance from the inlet is accompanied by a delay in time of the high and low tides. There is 190 minute delay in tides between the inlet and the farthest reach of the system.

Problem Assessment

Water quality problems associated with development within the watershed result primarily from septic systems and much less from runoff and fertilizers. The water quality problems affecting nutrient-enriched embayments generally include periodic decreases of dissolved oxygen, loss of eelgrass habitat, decreased diversity and quantity of benthic animals and periodic algae blooms. In the most severe cases, habitat degradation could lead to periodic fish kills, unpleasant odors and scums and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals. Coastal communities, including Dennis, rely on clean, productive and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing and boating, as well as commercial fin fishing and shell fishing. The continued degradation of this coastal embayment as described above will significantly reduce the recreational and commercial value and use of these important environmental resources.

Figure 3 shows how the population of Dennis has increased dramatically in the last 50 years -a more than 4 fold increase since 1950. Increases in N loading to estuaries are directly related to increasing development and population in the watershed. The increase in population contributes to a decrease in undeveloped land and an increase in septic systems, runoff from impervious surfaces and fertilizer use. All the residences in the Swan Pond River watershed are serviced by privately maintained conventional on-site septic systems with the exception of 29 innovative/alternative septic systems. There is no centralized wastewater treatment system in the watershed. These unsewered areas contribute significant nitrogen to the system through transport in direct groundwater discharges to estuarine waters and through surface water flows from freshwater tributaries and ponds.

Figure 3: Resident Population Trend for Dennis



Habitat and water quality assessments were conducted on this estuarine system based upon water quality monitoring data, changes in eelgrass distribution, time-series water column oxygen measurements and benthic community structure. As a basis for a nitrogen threshold determination, the MEP study focused on major habitat quality indicators: (1) bottom water dissolved oxygen and chlorophyll-*a* concentrations, (2) eelgrass distribution over time and (3) benthic animal communities (see Chapter VII of the Technical Report).

The Swan Pond River Estuarine System is a complex estuary composed of two functional types of component basins: open water embayment (Swan Pond) and tidal river (Swan Pond River), with the upper reaches supporting significant salt marsh area. Each of these functional components has different natural sensitivities to nitrogen enrichment and organic matter loading. In addition, the extensive salt marsh introduces a level of natural organic enrichment.

At present, the Swan Pond River estuarine system is showing differences in nitrogen enrichment and habitat quality among its various component basins with regions of clearly impaired habitat, however, there is a strong gradient. (Table 3) Swan Pond is a significantly impaired basin relative to benthic animal habitat but historically has not supported eelgrass. Nitrogen enrichment (through inputs and naturally low tidal exchange) has resulted in frequent large phytoplankton blooms, periodic hypoxia/anoxia, large macroalgal accumulations and a benthic community comprised of stress indicator species. The Swan Pond River is also nitrogen enriched, but has less nitrogen enrichment based primarily on its structure and high relative water turnover. While the lower reach (nearest the inlet) currently supports only high quality to moderately impaired benthic habitat, its loss of historical eelgrass beds indicates that it has become a significantly impaired basin relative to eelgrass habitat. The upper tidal reach of the Swan Pond River is intermediate in habitat quality between Swan Pond and the lower River. The upper tidal reach (above Rt. 28) is moderately to significantly impaired based upon its benthic animal habitat, due primarily to organic and nitrogen rich waters ebbing from Swan Pond and natural enrichment processes associated with its extensive wetlands. The result is high phytoplankton biomass with some oxygen depletion and organic enriched sediments and an animal community with very low diversity. The upper River has not historically supported eelgrass habitat.

The absence of eelgrass throughout the Swan Pond River estuary is consistent with the observed nitrogen and the chlorophyll *a* levels and functional basin types comprising this estuary. The lower Swan Pond River supported eelgrass beds in 1951 under lower nitrogen loading conditions. This eelgrass was lost sometime prior to 1995. However, given the sensitivity of eelgrass to declining light penetration resulting from nutrient enrichment and secondary effects of organic enrichment and oxygen depletion, the current absence of eelgrass within this system is expected given the high nitrogen levels and high chlorophyll *a* levels measured in all basins (>10µg/L chlorophyll *a*). Total nitrogen levels monitored throughout the Swan Pond River Estuarine System (range 0.45–1.55 mg/L) are higher than typically associated with eelgrass beds in southeastern Massachusetts (0.35 - 0.45 mg/L) and have resulted in the loss of historic eelgrass beds from this basin. Overall, the regions of significant and moderate habitat impairment comprise >90% of the estuarine area of the Swan Pond River system.

Table 3: Summary of Conditions Related to the Major Indicators of Habitat Impairment Observed in the Swan Pond River Estuarine System

Health Indicator	Swan Pond River		Swan Pond
	Upper River[1]	Lower River	
Dissolved Oxygen	<4 mg/L ~15% of 30 dates **MI-SI**	<4 mg/L 11%, <5 mg/L 40% of 30 dates **MI**	Periodically <1mg/L, <3 mg/L 11%, and <4 mg/L 18% **SI**
Chlorophyll	Ave 20 ug/L **SI**	10-15ug/L **MI-SI**	Ave. 15.3 ug/L, bloom >100 ug/L, mean 29 ug/L **SD**
Macroalgae	Patches of drift,Ulva, some filamentous **H-MI**	Patches of drift, Ulva, some filamentous **H-MI**	Dense patches of drift algae, Ulva, some filamentous, small patches of SAV, Ruppia, common to salt marshes **SD**
Eelgrass	**--**	Complete loss between 1951 and 1995 **SI**	**--**
Infaunal Animals	High numbers of individuals,low-mod number of species, low number of stress indicator species **MI-SI**	Mod to high number of individuals and species, stress indicator species ~20%of pop. **H-SI**	High number of individuals, very low diversity, ~50% stress indicator species **SI-SD**
Overall	Sustained high chlorophyll levels and periodic DO depletion. Dominated by outflows of low DO, high organic matter waters from Swan Pond **MI-SI**	Loss of eelgrass, infauna habitat stress indicator species, high diversity and evenness **MI**	Low diversity and evenness of infauna habitat, dominated by stress indicator species, oxygen stress, very high phytoplankton biomass, large macroalgal accumulations. **SI-SD**

H - Healthy Habitat Conditions*
MI – Moderately Impaired*
SI – Significantly Impaired- considerably and appreciably changed from normal conditions*
SD –Severely Degraded *
* - These terms are more fully described in MEP report "Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators" December 22, 2003
http://www.mass.gov/dep/water/resources/nitroest.pdf
-- no evidence this basin is supportive of eelgrass
[1] Tidal river with extensive salt marsh, adds natural to organic enrichment and low DO, primarily related to low oxygen ebb waters from Swan Pond. Data source Dennis Water Quality Monitoring Program (DWQMP 2005-2010).

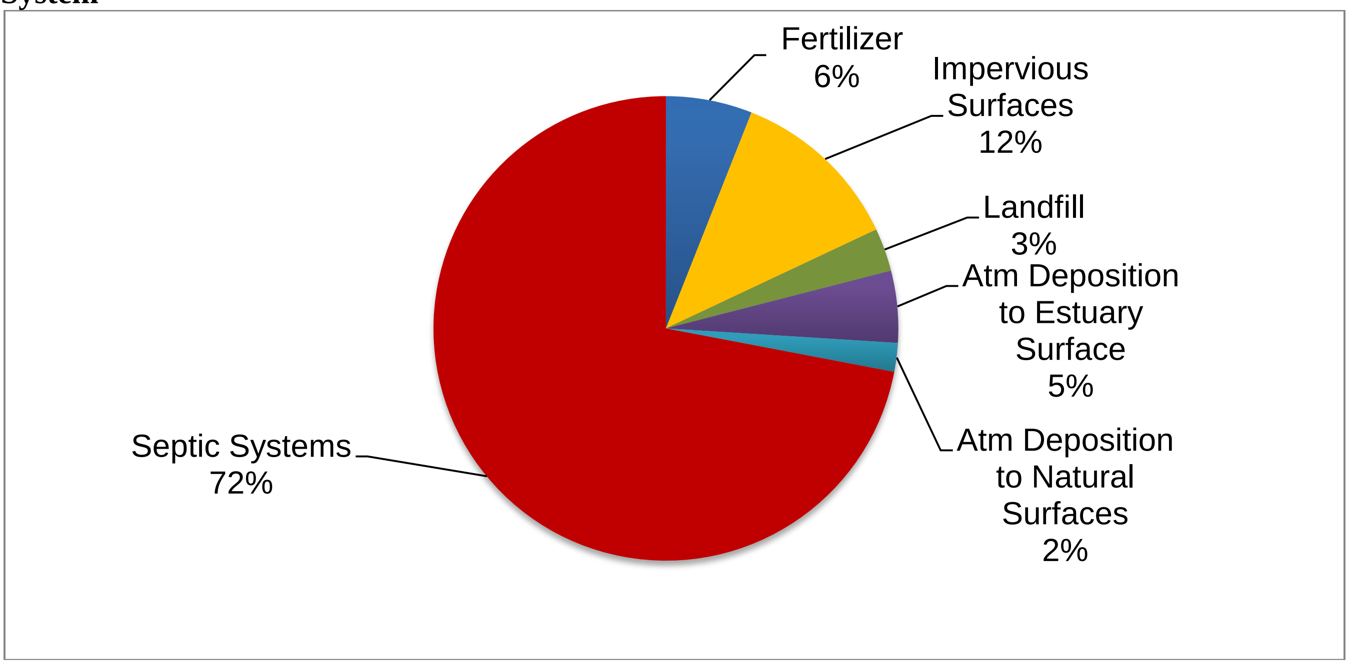
Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the town of Dennis as in most marine and coastal waters the limiting nutrient is N. Nitrogen concentrations beyond those expected naturally contribute to undesirable conditions including the severe impacts described above, through the promotion of excessive growth of plants and algae.

The embayments addressed in this TMDL report have had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Town of Dennis, SMAST, the USGS, and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report.

Figure 4 illustrates the sources of N to the Swan Pond River estuarine system. Most of the controllable N affecting these systems originates from on-site subsurface wastewater disposal systems (septic systems). The level of “controllability” of each source, however, varies widely:

Figure 4: Percent Contribution of Nitrogen Sources to the Swan Pond River Estuarine System



Atmospheric deposition to estuary surface– Although helpful, local controls are not adequate – it is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible, however the N from these sources might be subjected to enhanced natural attenuation as it moves towards the estuary.

Atmospheric deposition to natural surfaces (forests, fields, etc.) in the watershed – cannot be adequately controlled locally, however the N from these sources might be subjected to enhanced natural attenuation as it moves towards the estuary.

Fertilizer –Fertilizer and related N loadings can be reduced through best management practices (BMPs), bylaws and public education.

Impervious surfaces and storm-water runoff- sources of N can be controlled by BMPs, bylaws and storm-water infrastructure improvements and public education.

Landfill – the Town of Dennis owns a closed and capped landfill partially located within the Swan Pond River watershed and a portion of the nitrogen load from this landfill drains to the watershed. Related N loadings can be controlled through appropriate BMP and management techniques.

Nitrogen from sediments - control by such measures as dredging is not feasible on a large scale. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. Increased dissolved oxygen will help keep N from fluxing..

Septic system–are the largest sources of controllable N. These sources of N can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing N-reducing on-site wastewater treatment systems.

Cost/benefit analyses will have to be conducted on all possible N loading reduction methodologies in order to select the optimal control strategies, priorities and schedules.

Description of the Applicable Water Quality Standards

The water quality classifications of the saltwater portions of the Swan Pond River Estuarine System are SA (all surface waters subject to the rise and fall of the tide), and the freshwater portions of the system are classified as B. Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, and excess plant biomass and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) (MassDEP, 2007) contain descriptions of coastal and marine classes and numeric criteria for dissolved oxygen but have only narrative standards that relate to the other variables, as described below:

314 CMR 4.05(4) (a) Class SA. These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.

*314 CMR 4.05(4) (b)*Class SB. These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances; produce objectionable odor, color, taste, or turbidity; or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(b) states: "Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms."

314 CMR 4.05(5)(c) states, "Nutrients - Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department ."

314 CMR 4.05(4)(a)1- Class SA, Dissolved Oxygen -
Shall not be less than 6.0 mg/L. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

314 CMR 4.05(3)(b)1- Class B, Dissolved Oxygen -
Shall not be less than 6.0 mg/l in cold water fisheries and not less than 5.0 mg/l in warm water fisheries. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Thus, the assessment of eutrophication is based on site-specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the EPA in their draft Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (Environmental Protection Agency, 2001). The Guidance Manual notes that lakes, reservoirs, streams and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters tend to have unique characteristics and development of individual water body criteria is typically required.

Methodology - Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the MEP Technical Report. Those data were used by SMAST to assess the loading capacity of each embayment. Physical (Chapter V), chemical and biological (Chapters IV, VII, and VIII) data were collected and evaluated. The primary water quality objective was represented by conditions that:

1) restore the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish;
2) prevent harmful or excessive algal blooms;
3) restore and preserve benthic communities;
4) maintain dissolved oxygen concentrations that are protective of the estuarine communities.

The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach are summarized below.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics, and is characterized as follows:

- requires site specific measurements within the watershed and each sub-embayment;
- uses realistic "best-estimates" of N loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- spatially distributes the watershed N loading to the embayment;
- accounts for N attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes N regenerated within the embayment;
- is validated by both independent hydrodynamic, N concentration, and ecological data;
- is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model has been applied previously to watershed N management in over 60 embayments thus far throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment becomes a N management-planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. Also, since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. It should be noted that this approach includes high-order, watershed and sub-watershed scale modeling necessary to develop critical nitrogen targets for each major sub-embayment. The models, data and assumptions used in this process are specifically intended for the purposes stated in the MEP Technical Report, upon which this TMDL is based. As such, the Linked Model process does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of nitrogen through groundwater from specific sources. In addition, any determinations related to direct and immediate hydrologic connection to surface waters are beyond the scope of the MEP's Linked Model process.

The Linked Model provides a quantitative approach for determining an embayment's (1) N sensitivity, (2) N threshold loading levels (TMDL) and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation and recycling and variations in tidal hydrodynamics (Figure I-4 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

• Monitoring - multi-year embayment nutrient sampling

• Hydrodynamics
  - embayment bathymetry (depth contours throughout the embayment)
  - site-specific tidal record (timing and height of tides)
  - water velocity records (in complex systems only)
  - hydrodynamic model

• Watershed Nitrogen Loading
  - watershed delineation
  - stream flow (Q) and N load
  - land-use analysis (GIS)
  - watershed N model

• Embayment TMDL - Synthesis
  - linked Watershed-Embayment Nitrogen Model
  - salinity surveys (for linked model validation)
  - rate of N recycling within embayment
  - dissolved oxygen record
  - chlorophyll *a* record
  -eelgrass survey
  - infaunal survey (in complex systems)

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific embayments, for the purpose of developing target N loading rates, includes:

1) Selecting one or two stations within the embayment system located close to the inland-most reach or reaches which typically have the poorest water quality within the system. These are called "sentinel" stations;

2) Using site-specific information and a minimum of three years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft target threshold N concentrations that were developed as the initial step of the MEP process. The target threshold N concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

3) Running the calibrated water quality model using different watershed N loading rates to determine the loading rate that will achieve the target threshold N concentration at the sentinel station. Differences between the modeled N load required to achieve the target threshold N concentration and the present watershed N load represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses and the modeling activities described above resulted in four major outputs that were critical to the development of the TMDL. Two outputs relate to **N concentration:**

- the present N concentrations in the sub-embayments
- site-specific target threshold N concentrations

And, two outputs relate to **N loadings:**

- the present N loads to the sub-embayments
- load reductions necessary to meet the site specific target N concentrations

In summary: if the water quality standards are met by reducing the N concentration (and thus the N load) at the sentinel station(s), then the water quality goals will be met throughout the entire system.

A brief overview of each of the outputs follows:

Nitrogen concentrations in the embayment

1) Observed "present" conditions:

Table 4 presents the average concentrations of N measured in this estuarine system from data collected by the Town of Dennis water quality monitoring program during the period 2005-2010. The overall means and standard deviations of the averages are presented in Appendix A (taken from Table VI-1 of the MEP Technical Report). Water quality sampling stations are shown in Figure 5 below. The sentinel station is SWP-2 within the middle of the lower reach of the river.

Table 4: Observed Present Nitrogen Concentrations and Sentinel Station Target Threshold Nitrogen Concentration for the Swan Pond River Estuarine System

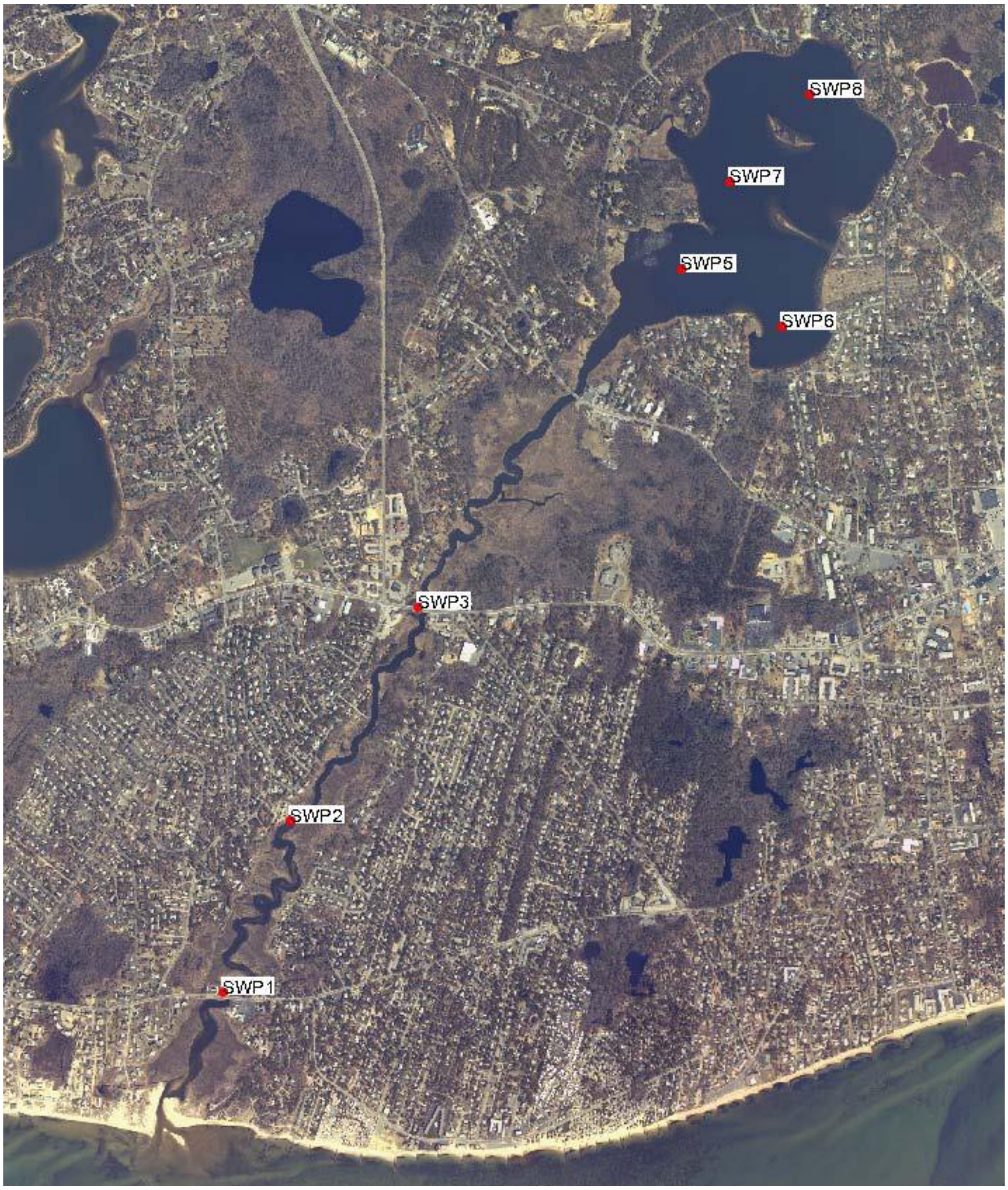
Sub-embayment	Observed Nitrogen Concentration [1](mg/L)	Target Threshold Nitrogen Concentration(mg/L)
Lower River	0.556 - 0.673[2]	0.40[4]
Upper River	0.862	
Swan Pond	1.036-1.197[3]	

[1]Average total N concentrations from present loading based on an average of the annual N means from 2005-2010.
[2] Range of means from multiple stations (SWP-1,SWP-2)
[3] Range of means from multiple stations (SWP-5, SWP-6, SWP-7, SWP-8)
[4]Targetthreshold Nconcentration at sentinel station SWP-2

2) Modeled site-specific target threshold N concentrations:

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. This is called the *target threshold nitrogen concentration*. Prior to conducting the analytical and modeling activities described above, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific target threshold N concentrations by using the specific physical, chemical and biological characteristics of each sub-embayment.

Figure 5: Water Quality Sampling Stations in the Swan Pond River Estuarine System



*Sentinel Station is SWP-2

The target threshold nitrogen concentration for the Swan Pond River Estuary is 0.40 mg/L at sentinel station, SWP-2 (Table 4). This value was determined as follows:

The approach for determining nitrogen loading rates which will maintain acceptable habitat quality throughout an embayment system is to first identify a sentinel location within the embayment and second to determine the nitrogen concentration within the water column which will restore that location to the desired habitat quality. The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels. Once the sentinel site and its target threshold nitrogen concentration are determined, the MEP study modeled nitrogen loads until the targeted nitrogen concentration was achieved.

The determination of the critical nitrogen threshold for maintaining high quality habitat with the Swan Pond River estuarine system is based on the nutrient and oxygen levels, temporal trends in eelgrass distribution and benthic community indicators. The primary habitat issues within the Swan Pond River estuarine system relate to the loss of the eelgrass beds from the lower Swan Pond River as well as the highly degraded benthic animal habitat in the upper estuary, specifically in Swan Pond.

The loss of eelgrass classifies the lower Swan Pond River as "significantly impaired", although this estuarine basin presently supports high quality to moderately impaired infaunal communities. The impairments to both the infaunal habitat and the eelgrass habitat within the component basins of the Swan Pond River Estuarine System are supported by the variety of other indicators including oxygen depletion, chlorophyll-*a*, and TN levels, all of which support the conclusion that these impairments are the result of nitrogen enrichment, primarily from watershed nitrogen loading (Table 3).The upper tidal river is partially naturally nutrient and organic matter enriched (due to extensive salt marsh), however, the existing benthic communities and high chlorophyll-*a* level still suggest a moderate level of impairment for this portion of the overall Swan Pond system.

The Swan Pond River Estuarine System exhibits a gradient of nutrient related habitat degradation from the most inland reach of the overall system (Swan Pond) to higher quality habitat within the Swan Pond River near the tidal inlet. The gradient in impairment follows the gradient in nitrogen enrichment, where Swan Pond has very high tidally averaged modeled TN levels (1.06-1.21 mg/L) declining to the Lower River nearest the tidal inlet (0.47-0.66 mg/L). While the Lower River exhibits the lowest nitrogen levels within the system, the levels are still quite high and indicate a basin incapable of supporting eelgrass beds and with a moderate level of impairment to benthic animal habitat.

The eelgrass and water quality information supports the conclusion that eelgrass beds within the lower reach of the Swan Pond River should be the primary target for restoration of the Swan Pond River Estuarine System and that restoration requires appropriate nitrogen management. From the historical analysis, it appears that only a modest acreage of eelgrass can be restored (all in the lower reach), achieving its restoration will be coupled with restoration of large areas of severely degraded benthic animal habitat within the upper estuary (above Rt. 28), more than 150 acres in Swan Pond alone as well as reduced oxygen depletion that presently cause periodic fish kills. Therefore, the sentinel station for the Swan Pond River estuarine system is located at the long-term water quality monitoring station within the middle of the lower reach of the River (SWP-2). This site was selected based upon its location at the upper most extent of the documented eelgrass coverage in this estuary.

With the sentinel station located at the uppermost extent of the historical eelgrass coverage, the target nitrogen concentration (tidally averaged TN) for restoration of eelgrass at the sentinel location within the lower reach of the Swan Pond River was determined to be 0.40 mg/L. As there has not been eelgrass habitat within the Swan Pond River Estuary for over a decade, this threshold was based upon comparison to other local embayments of similar depths and structure that have been reviewed under MEP analysis. The historic Swan Pond River eelgrass habitat appears to have been patchy and like other similar basins, found mainly within the areas of more stable sediments. The threshold for eelgrass restoration in Swan Pond River is similar to those selected by the MEP for nearby systems like the Bournes Pond Estuary, where eelgrass has historically been confined to the lower estuarine basin (main open water stem of the channel) at TN levels of 0.42 mg/L, although at a shallower depth than the channel of lower Swan Pond River. Similarly other MEP observations found that the lower reach of the Green Pond Estuary, supports a sparse (slowly declining) eelgrass "bed" at tidally averaged TN levels of 0.41 mg/L, while the region near the inlet to Waquoit Bay, eelgrass patches persist at 0.395 mg/L. Given the depth of the lower Swan Pond River a lower threshold than Bournes Pond and about the same as the patches in Waquoit Bay is appropriate. It should be noted that this threshold targets eelgrass habitat throughout the lower reach of the River, not just the shallow fringing areas.

Although the target threshold N concentration is established for eelgrass habitat restoration (and associated water clarity, shellfish and fisheries resources) benthic infaunal habitat quality must also be supported. Benthic animals are more tolerant of nutrient enrichment than eelgrass which requires clear waters and high oxygen levels. At present, the regions with moderately to significantly impaired infaunal habitat within the Swan Pond River Estuarine System have average tidal nitrogen concentrations of 0.66 – 1.21 mg N/L. The observed impairment is consistent with MEP observations in other enclosed basins such as Perch Pond, Bournes Pond, Popponesset Bay where levels of <0.50 mg N/L were supportive of healthy infaunal habitat and where moderately impaired habitat was found around 0.60 mg N/L.

Based upon these observations, the MEP study concluded that an upper limit of 0.50 mg/L tidally averaged TN would support healthy infaunal habitat in the upper Swan Pond River, but given the shallow nature of Swan Pond and its significant salt marsh resources, a tidally averaged TN of <0.55 mg/L was appropriate. This higher threshold in Swan Pond is similar to those selected for Lewis Pond in Parker's River and the upper reach of the Mashpee River and is only slightly higher than the non-wetland influenced basins of the upper Bass River. Since the goal is restoration throughout Swan Pond, the benthic animal restoration TN level targets the pond-wide tidally averaged TN level (average long-term monitoring stations, SWP- 5,6,7,8). Although these secondary infaunal criteria will not be used as target threshold nitrogen concentrations they will serve as a check of the conditions within the pond and Upper River when the target threshold nitrogen level has been met at the sentinel station.

The findings of the analytical and modeling investigations for the Swan Pond River estuarine system are discussed and explained below.

The target threshold N concentration for an embayment represents the average water column concentration of N that will support the habitat quality and dissolved oxygen concentrations being sought. The water column N level is ultimately controlled by the integration of the watershed N load, the N concentration in the inflowing tidal waters (boundary condition), and dilution and flushing via tidal flows. The water column N concentration is modified by the extent of sediment uptake and/or regeneration and by direct atmospheric deposition.

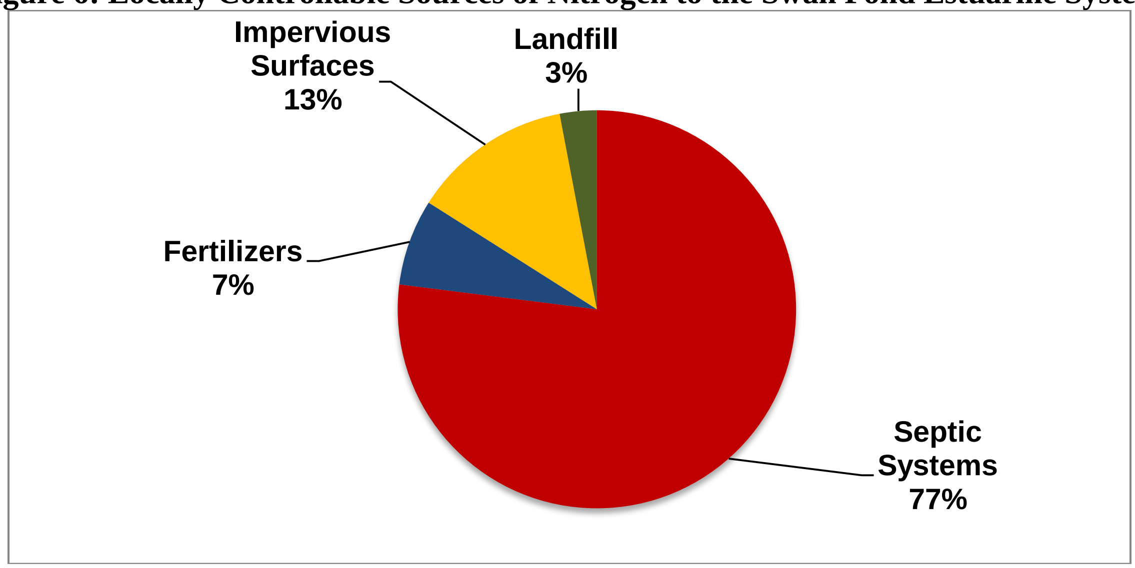
Target threshold N concentrations in this study were developed to restore or maintain SA waters or high habitat quality. In this system, high habitat quality was defined as stable eelgrass beds in the lower reach of Swan Pond River and healthy infaunal habitat throughout the system.

Nitrogen loadings to the embayment

1) Present Loading rates:

In the Swan Pond River Estuarine System overall, the highest N loading from ***controllable*** sources is from on-site wastewater treatment systems. The MEP Technical Report calculates that septic systems account for 77% of the controllable N load to the overall system. Other controllable sources include the landfill (3%), fertilizers (7%), and runoff from impervious surfaces (13%) (Figure 6). Nitrogen rich sediments are a minor source in this system and are not considered feasibly controllable. However, reducing the N load to the estuary will also reduce N in the sediments since the magnitude of the benthic contribution is related to the watershed load. Atmospheric nitrogen deposition to the estuary and watershed surface area was also a minor and uncontrollable source to this system.

Figure 6: Locally Controllable Sources of Nitrogen to the Swan Pond Estuarine System



A subwatershed breakdown of N loading, by source, is presented in Table 5. The data on which Table 5 is based can be found in Table ES-1 and Table IV-3 of the MEP Technical Report.

As previously indicated, the present N loadings to this estuary system must be reduced in order to restore the impaired conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL is modeling and analysis to determine the loadings required that will achieve the target threshold N concentrations.

Table 5: Present Nitrogen Loadings to the Swan Pond River Estuarine System*

Sub-embayment	Present Land Use Load[1] (kg N/day)	Present Septic System Load (kg N/day)	Present Watershed Load[2] (kg N/day)	Present Atmospheric Deposition[3] (kg N/day)	Present Benthic Flux[4] (kg N/day)	Total Nitrogen Load from All Sources[5] (kg N/day)
Swan Pond	5.065	13.058	18.123	1.885	-3.473	16.535
Swan Pond River –North (upper)	1.625	8.411	10.036	0.104	0.385	10.525
Swan Pond River – South (lower)	4.038	11.518	15.556	0.233	-1.346	14.276
Swan Pond System Total	10.728	32.987	43.715	2.222	-4.434	41.336

* From Table ES-1 in the MEP Technical Report,
[1]Includes fertilizers, runoff, landfill and atmospheric deposition to lakes and natural surfaces (ie. non-wastewater loads).
[2]Includes fertilizer, runoff, landfill, atmospheric deposition to lakes and natural surfaces and wastewater inputs.
[3]Atmospheric deposition to the estuarine surface only.
[4]Nitrogen loading from sediments.
[5]Composed of natural background, fertilizer, runoff, landfill, wastewater, atmospheric deposition and benthic flux nitrogen input.

2) Nitrogen loads necessary for meeting the site-specific target threshold N concentrations:

Table 6 lists the present watershed N loadings from the Swan Pond River estuarine system and the percent watershed load reductions necessary to achieve the target threshold N concentration at the sentinel station (see following section).

It is very important to note that load reductions can be produced through a variety of strategies: reduction of any or all sources of N; increasing the natural attenuation of N within the freshwater systems; and/or modifying the tidal flushing through inlet reconfiguration (where appropriate). This scenario establishes the general degree and spatial pattern of reduction that will be required for restoration of the N impaired portions of this system. The town of Dennis should take any reasonable actions to reduce the controllable N sources.

Table 6: Present Watershed Nitrogen Loading Rates, Calculated Loading Rates that are Necessary to Achieve Target Threshold Nitrogen Concentrations, and the Percent Reductions of the Existing Loads Necessary to Achieve the Target Threshold Loadings*

Sub-embayment	**Present Total Watershed Load [1] (kg/day)**	**Target Threshold Watershed Load[2] (kg/day)**	**% Watershed Load Reductions Needed to Achieve Target**
Swan Pond	18.123	5.063	-72.1%
Swan Pond River – North (upper)	10.036	1.625	-83.8%
Swan Pond River – South (lower)	15.556	4.038	-74.0%
Swan Pond River System Total	43.715	10.726	-75.5%

[1] Composed of fertilizer, runoff, landfill, atmospheric deposition to lakes and natural surfaces (not estuarine surface) and wastewater inputs.
[2]Target threshold watershed load is the N load from the watershed (including natural background) needed to meet the target threshold N concentration identified in Table 4, above.
*From Tables ES-2and VIII-3 in the MEP Technical Report.

Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. The TMDLs are established to protect and/or restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no "numerical" water quality standards for N, the TMDLs for the Swan Pond River estuarine system are aimed at establishing the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The development of a TMDL requires detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time) for each waterbody system. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll *a* and benthic infauna.

The TMDL can generally be defined by the equation: ***TMDL = BG + WLAs + LAs + MOS***

Where:

TMDL = loading capacity of receiving water
BG = natural background
WLAs = portion allotted to point sources
LAs = portion allotted to (cultural) non-point sources
MOS = margin of safety

Background Loading

Natural background N loading is included in the loading estimates, but is not quantified or presented separately. Background loading was calculated on the assumption that the entire watershed is forested with no anthropogenic sources of N. It is accounted for in this TMDL but not defined as a separate component. Readers are referred to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions.

Waste Load Allocations

Waste load allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Swan Pond River estuarine system there are no permitted surface water discharges in the watershed with the exception of stormwater. A TMDL may establish a specific WLA for an identified source or, as in the case of stormwater, may establish an aggregate WLA that applies to numerous sources. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of stormwater also be included in the waste load component of the TMDL. In the Swan Pond River estuarine system this load includes runoff from impervious surfaces.

For purposes of the Swan Pond River TMDLs, MassDEP also considered the nitrogen load reductions from regulated MS4 sources necessary to meet the target nitrogen concentrations. In estimating the nitrogen loadings from regulated stormwater sources, MassDEP considered that most stormwater runoff in the MS4 communities is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod and the Islands consists primarily of glacial outwash sands and gravels, and water moves rapidly through this type of soil profile. A systematic survey of stormwater conveyances on Cape Cod and the Islands was never undertaken prior to the MEP study used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod and the Islands are known to MassDEP to have been designed as leaching catch basins in light of the permeable overburden. MassDEP, therefore, recognized that most stormwater that enters a catch basin in the regulated area will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

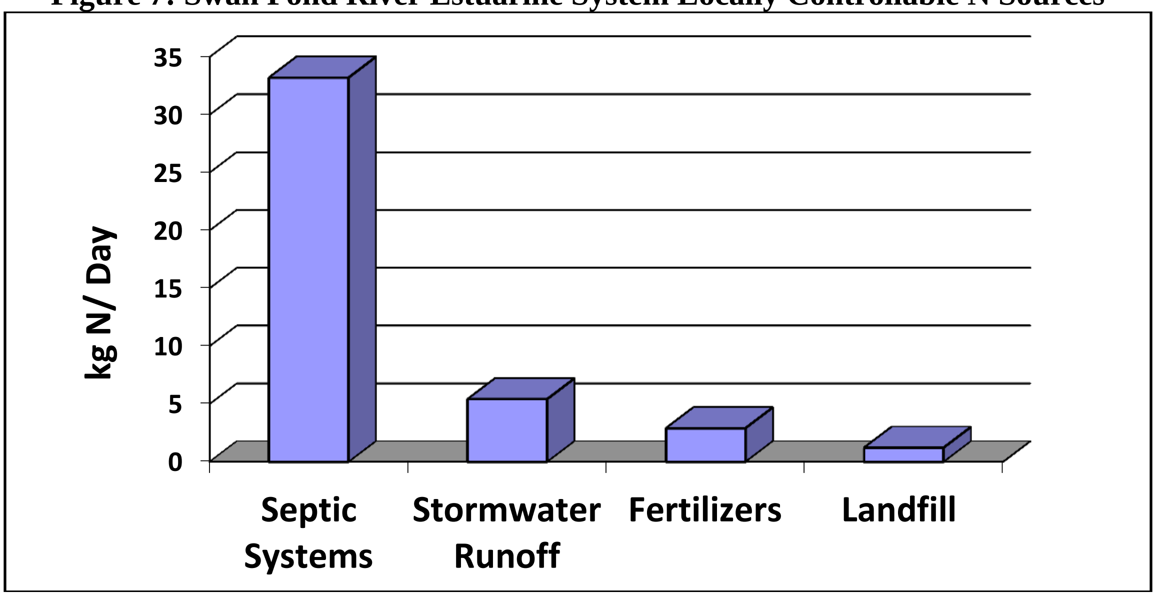
As described in the Methodology Section (above), the Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source. However, MassDEP also considered that some stormwater may be discharged directly to surface waters through outfalls. In the absence of specific data or other information to accurately quantify stormwater discharged directly to surface waters, MassDEP assumed that all impervious surfaces within 200 feet of the shoreline, as calculated from MassGIS data layers, would discharge directly to surface waters, whether or not it in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 feet from the shoreline would be directly discharged into surface waters. Although the 200 foot approach provided a gross estimate, MassDEP considered it a reasonable and conservative approach given the lack of pertinent data and information about stormwater collection systems on Cape Cod.

For the Swan Pond River Estuarine System this calculated stormwater WLA is 0.54% of the total N load or 0.25 kg/day as compared to the overall N load of 46.07 kg/day to the embayment (see Appendix B for details). This conservative load is negligible when compared to other sources.

Load Allocations

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Swan Pond River estuarine system the locally controllable nonpoint source loadings are from on-site subsurface wastewater disposal systems (septic systems) and other land uses which include stormwater runoff, (except from impervious cover within 200 feet of the waterbody which is defined above as part of the waste load)fertilizers and the landfill. Figure 6 (above) and Figure 7 (below) illustrate that septic systems are the most significant portion of the controllable N load (77% or 33 kg N/day), with fertilizers and runoff contribution a distant second (2.9 and 5.4kg N/day, respectively) and the landfill load even less (1.2kg N/day). In addition, there are nonpoint sources of N from sediments, natural background and atmospheric deposition that are not feasibly controllable.

Figure 7: Swan Pond River Estuarine System Locally Controllable N Sources



Generally, stormwater that is subject to the EPA Phase II Program is considered a part of the waste load allocation, rather than the load allocation (see waste load allocation discussion). As discussed above and presented in Chapter IV, V, and VI, of the MEP Technical Report, on Cape Cod and the Islands the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater, thus defining the stormwater in pervious areas to be a component of the nonpoint source load allocation. Therefore, the TMDL accounts for storm-water and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and stormwater for the purpose of developing control strategies.

The sediment loading rates incorporated into the TMDL are lower than the existing benthic input listed in Table 5 above because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments and therefore, over time, reductions in loadings from the sediments will occur. Benthic N flux is a function of N loading and particulate organic N (PON). Projected benthic fluxes are based upon projected PON concentrations and watershed N loads and are calculated by multiplying the present N flux by the ratio of projected PON to present PON using the following formulae:

Projected N flux = (present N flux) (PON projected / PON present)

When: $PON\ projected = (R_{load})\ (D_{PON}) + PON_{present\ offshore}$

When: $R_{load} = (projected\ N\ load) / (Present\ N\ load)$

And: D_{PON} is the PON concentration above background determined by:

$D_{PON} = (PON_{present\ embayment} - PON_{present\ offshore})$

The benthic flux modeled for the Swan Pond River estuarine system is reduced from existing conditions based on the load reduction and the observed PON concentrations within each sub-embayment relative to Nantucket Sound (boundary condition). The benthic flux input to each sub-embayment was reduced (toward zero) based on the reduction of N in the watershed load. There was one exception to this rule. Since there was a negative benthic flux (nutrient uptake) recorded in the Swan Pond and in the lower (south) Swan Pond River under present conditions, a more conservative approach was used for these segments in the TMDL by assuming zero benthic flux for these segments in the future. This conservative approach was used and is considered part of the margin of safety in the TMDL.

The loadings from atmospheric sources incorporated into the TMDL however, are the same rates presently occurring because, as discussed above, local control of atmospheric loadings is not considered feasible.

Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20©, 40C.G.R. para 130.7©(1)].The MOS must be designed to ensure that any uncertainties in the data or calculations used to link pollutant sources to water quality impairment modeling will be accounted for in the TMDL and ensure protection of the beneficial uses. The EPA’s 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for the Swan Pond River Estuarine System TMDL is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing estuarine conditions are not well known at this time (http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. In light of these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

Conservative assumptions that support an implicit MOS:

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayment. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation and dilution, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. In this context, "direct groundwater discharge" refers to the portion of fresh water that enters an estuary as groundwater seepage into the estuary itself, as opposed to the portion of fresh water that enters as surface water inflow from streams, which receive much of their water from groundwater flow. Nitrogen from the upper watershed regions, which travels through ponds or wetlands, almost always enters the embayment via stream flow, and is directly measured (over 12-16 months) to determine attenuation. In these cases the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers that have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been >95%. Since the water quality model incorporates all of the outputs from the other models, this excellent fit indicates a high degree of certainty in the final result. The high level of accuracy of the model provides a high degree of confidence in the output; therefore, less of a margin of safety is required.

In the Swan Pond River Estuarine System, Eagle Pond and Hyda Way Creek were the only freshwater sources of sufficient size to have a delineated sub-watershed. This pond and stream lacked sufficient data to calculate an attenuation factor so a conservative value of 50% was applied as more protective and defensible. These attenuation factors were higher than that used in the land-use model.

Similarly, the water column N validation dataset was also conservative. The model is validated to measured water column N. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement two times higher than the next highest data point in the series raises the average 0.05 mg N/L, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

Finally, the predicted reductions in benthic regeneration of N are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of PON, due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced, it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase. It was also conservatively assumed that the present benthic flux uptake measured in the Swan Pond System (-4.434 kg/day) does not exist under future loading conditions and as such was designated as "0" for purposes of the TMDL.

Benthic regeneration of N is dependent upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions (1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs and (2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

2. Conservative sentinel station/target threshold nitrogen concentration

Conservatism was used in the selection of the sentinel stations and target threshold N concentrations. The sites were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentration. Meeting the target threshold N concentrations at the sentinel stations will result in reductions of N concentrations in the rest of the system.

3. Conservative approach

The target loads were based on tidally averaged N concentrations on the outgoing tide, which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides and therefore this approach is conservative.

Finally, the linked model accounted for all stormwater loadings and groundwater loadings in one aggregate allocation as a non point source and this aggregate load is accounted for in the load allocation. The method of calculating the WLA in the TMDL for regulated stormwater was conservative as it did not disaggregate this negligible load from the modeled stormwater LA, hence this approach further enhances the margin of safety.

In addition to the margin of safety within the context of setting the N threshold levels as described above, a programmatic margin of safety also derives from continued monitoring of these embayments to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

Seasonal Variation

Since the TMDLs for the waterbody segments are based on the most critical time period, i.e. the summer growing season, the TMDLs are protective for all seasons. The daily loads can be converted to annual loads by multiplying by 365 (the number of days in a year). Nutrient loads to the embayment are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of controls necessary to control the N load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual manipulation since the majority of the N is from non-point sources. Thus, the annual loads make sense since it is difficult to control non-point sources of N on a seasonal basis and N sources can take considerable time to migrate to impacted waters.

TMDL Values for the Swan Pond River Estuarine System

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of the embayment were calculated by considering all sources of N grouped by natural background, point sources and non-point sources. A more meaningful way of presenting the loadings data from an implementation perspective is presented in Table 7below and Appendix C.

In this table the N loadings from the atmosphere are listed separately from the target watershed threshold loads which are composed of natural background N along with locally controllable N from the on-site subsurface wastewater disposal systems, the landfill, storm-water runoff and fertilizer sources. In the case of the Swan Pond River Estuarine System the TMDLs were calculated by projecting reductions in locally controllable septic systems throughout the entire watershed. Once again the goals of these TMDLs are to achieve the identified target threshold N concentration at the identified sentinel station. The target loads identified in Table 7 represents one alternative-loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

Table 7: The Total Maximum Daily Loads (TMDL) for the Swan Pond Estuarine System

Sub-embayment	Target Threshold Watershed Load[1] (kg N/day)	Atmospheric Deposition (kg N/day)	Nitrogen Load from Sediments[2] (kg N/day)	TMDL[3] (kg N/day)
Swan Pond	5.063	1.885	0	**6.948**
Swan Pond River- North (upper)	1.625	0.104	0.150	1.879
Swan Pond River- South (lower)	4.038	0.233	0	4.271
Swan Pond River				**6.15**
Swan Pond River System Total	10.726	2.222	0.150	**13.098**

[1] Target threshold watershed load (including natural background) is the load from the watershed needed to meet the embayment target threshold nitrogen concentration identified in Table 4.
[2] Projected sediment N loadings obtained by reducing the present benthic flux loading rates (Table 5) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON. (Negative fluxes set to zero.)
[3] Sum of target threshold watershed load, sediment load and atmospheric deposition load.

Implementation Plans

The critical element of this TMDL process is achieving the specific target threshold N concentration for the sentinel station presented in Table 4 above that is necessary for the restoration and protection of water quality and eelgrass habitat within the Swan Pond River Estuarine System. In order to achieve these target threshold N concentrations, N loading rates must be reduced throughout the harbor embayment system. Table 7, above, lists the target threshold watershed loads for this embayment. If this threshold load is achieved, this embayment will be protected.

Septic Systems:
Table 8 below presents a load reduction scenario based solely on reducing the septic loads from the Swan Pond River Estuary watershed. As previously noted, there is a variety of loading reduction scenarios that could achieve the target threshold N concentrations. Local officials can explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated however, that any alternative implementation strategies will be protective of the entire embayment system and that none of the embayment will be negatively impacted. To this end, additional linked model runs can be performed by the MEP to assist the planning efforts of the town in achieving target N loads that will result in the desired target threshold N concentration.

Table 8: Summary of the Present Septic System Loads, and the Loading Reductions Necessary to Achieve the TMDL by Reducing Septic System Loads Only[1]

Sub-embayment	Present Septic Load (kg/day)	Threshold Septic Load (kg/day)	Threshold Septic Load % Change
Swan Pond	13.058	0.0	-100%
Swan Pond River- North (upper)	8.411	0.0	-100%
Swan Pond River- South (lower)	11.518	0.0	-100%

[1]Note: From Table VIII-2 of the MEP Technical Report.

The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under the Clean Water Act Section 208. If a community chooses to implement TMDL measures without a CWMP it must demonstrate that these measures will achieve the target threshold N concentration. (Note: Communities that choose to proceed without a CWMP will not be eligible for State Revolving Fund 0% loans.)

Because the vast majority of controllable N load is from septic systems for private residences the CWMP should assess the most cost-effective options for achieving the target N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations and denitrifying systems for all private residences.

Stormwater:
EPA and MassDEP authorized most of the watershed community of Dennis for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. EPA and MassDEP reissued the MS4 permit in April 2016. The reissued permit takes effect on March 31, 2017. The NPDES permits issued in Massachusetts do not establish numeric effluent limitations for stormwater discharges, rather, they establish narrative requirements, including best management practices, to meet the following six minimum control measures and to meet State Water Quality Standards.

1. Public education and outreach particularly on the proper disposal of pet waste,
2. Public participation/involvement,
3. Illicit discharge detection and elimination,
4. Construction site runoff control,
5. Post construction runoff control, and
6. Pollution prevention/good housekeeping.

As part of their applications for Phase II permit coverage, communities must identify the best management practices they will use to comply with each of these six minimum control measures and the measurable goals they have set for each measure. Therefore, compliance with the requirements of the Phase II stormwater permit in the Town of Dennis will contribute to the goal of reducing the nitrogen load as prescribed in this TMDL for the Swan Pond River estuarine system watershed.

Climate Change:
MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are possible based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011Climate Change Adaptation Report: http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and precipitation rates in the Northeast could increase by as much as 20 percent. However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy http://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdfstates: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For estuarine TMDLs in southeastern Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (National Center for Environmental Assessment, Washington D.C.; EPA/600/R-12/058F). The closest watershed to southeastern Massachusetts that was examined in this study is a New England coastal basin located between Southern Maine and Central Coastal Massachusetts. These watersheds do not encompass any of the watersheds in the Massachusetts Estuary Project (MEP) region, and it has vastly different watershed characteristics, including soils, geography, hydrology and land use – key components used in a modeling analysis. The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from past experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the MEP region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program (2008) to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the nitrogen loadings to the Swan Pond River Estuary the TMDL can be reopened, if warranted.

The Town of Dennis is urged to meet the target threshold N concentrations by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in on-site subsurface wastewater disposal system loadings as well as reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater Best Management Practices (BMPs).

It should also be noted that a very small portion of the Town of Brewster is in the headwaters (North Dennis Wells subwatershed) of this system. An even smaller portion of Harwich is in the Swan Pond watershed. Thus the development of any implementation plan should also include these towns when coordinating efforts to maximize the reduction in N loading where possible and appropriate.

MassDEP's MEP Implementation Guidance report: http://www.mass.gov/dep/water/resources/coastalr.htm#guidance provides N loading reduction strategies that are available to Dennis and could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants

        - Municipal Treatment Plants and Sewers
- Tidal Flushing
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Storm-water Control and Treatment *
    - Source Control and Pollution Prevention
    - Storm-water Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts
- Land Use Planning and Controls
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient Trading

*Dennis is one of the 237 communities in Massachusetts covered (at least in part) by the Phase II storm-water program requirements.

Monitoring Plan

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that implementation will be conducted through an iterative process where adjustments maybe needed in the future. The two forms of monitoring include 1) tracking implementation progress as approved in the CWMP and 2) monitoring water quality and habitat conditions in the estuaries, including but not limited to, the sentinel stations identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL report and the MEP Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities, and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by the Department tracking progress on the agreed upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality, MassDEP believes that an ambient monitoring program much reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL values are not fixed, the target threshold N concentrations at the sentinel stations are fixed. Through discussions amongst the MEP it is generally agreed that existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes. Although more specific details need to be developed on a case-by-case basis, MassDEP believes that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, in addition to the above, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations as a result of restoration efforts.

The MEP will continue working with the watershed communities to develop and refine monitoring plans that remain consistent with the goals of the TMDL. Through the adaptive management approach ongoing monitoring will be conducted and will indicate if water quality standards are being met. If this does not occur other management activities would have to be identified and considered to reach to goals outlined in this TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

Reasonable Assurances

MassDEP possesses the statutory and regulatory authority, under the water quality standards and/or the State Clean Water Act (CWA), to implement and enforce the provisions of the TMDL through its many permitting programs including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Dennis has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The Town expects to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems and storm-water runoff (including fertilizers), and to prevent any future degradation of these valuable resources.

Moreover, reasonable assurances that the TMDL will be implemented include enforcement of regulations, availability of financial incentives and local, state and federal programs for pollution control. Stormwater NPDES permit coverage will address discharges from municipally owned storm-water drainage systems. Enforcement of regulations controlling non-point discharges include local implementation of the Commonwealth's Wetlands Protection Act and Rivers Protection Act, Title 5 regulations for on-site subsurface wastewater disposal systems and other local regulations (such as the Town of Rehoboth's stable regulations).

Financial incentives include federal funds available under Sections 319 and 604 programs of the CWA, which are provided as part of the Performance Partnership Agreement between MassDEP and EPA. Other potential funds and assistance are available through the Massachusetts Department of Agriculture's Enhancement Program and the United States Department of Agriculture's Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

As the Town implements these TMDLs, the loading values (kg/day of N) will be used by MassDEP for guidance for permitting activities and should be used by the community as a management tool.

Public Participation

To be completed after public notice and public meeting held.

Public meetings to present the results of and answer questions on this TMDL were held on XXX in the XXXX meeting room. XXXXX (MassDEP) summarized the Mass Estuaries Project and described the Draft Nitrogen TMDL Report findings. Public comments received at the public meetings and comments received in writing within a 30-day comment period following the public meeting were considered by the Department. This final version of the TMDL report includes both a summary of the public comments together with the Department's response to the comments and scanned images of the attendance sheets from the meetings (Appendix D). MEP representatives at the public meetings included XXXXXXX.

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Appendix A

Table A-1: Summary of the Nitrogen Concentrations for the Swan Pond River Estuarine System.
(from Chapter VI of the MEP Technical Report)

Town of Dennis water quality monitoring data and modeled Nitrogen concentrations for the Swan Pond River System. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means.

Sub-embayment	Station	2005 Mean	2006 Mean	2007 Mean	2008 Mean	2009 Mean	2010 Mean	Mean	s.d. all data	N	Model Min	Model Max	Model Avg.
Lower Swan River	SWP-1	0.494	0.640	0.540	0.490	0.449	0.712	0.556	0.134	38	0.315	1.050	0.465
Lower Swan River	SWP-2	0.581	0.825	0.607	0.567	0.688	0.773	0.673	0.188	30	0.325	1.175	0.662
Upper Swan River	SWP-3	0.803	1.015	0.781	0.851	0.875	0.841	0.862	0.282	30	0.335	1.206	0.827
Main Pond	SWP-5	0.963	1.135	1.133	0.954	0.979	0.971	1.036	0.279	29	0.570	1.216	1.056
Main Pond	SWP-6	0.933	0.971	1.433	0.879	1.268	1.181	1.123	0.331	26	1.090	1.196	1.143
Main Pond	SWP-7	1.039	1.141	1.412	1.141	1.260	1.178	1.197	0.395	59	1.112	1.223	1.168
Upper Pond	SWP-8	1.098	1.113	1.199	1.547	1.063	1.163	1.159	0.336	28	1.146	1.262	1.207

Appendix B

Table B-1: The Swan Pond River Estuarine System estimated waste load allocation (WLA) from runoff of all impervious areas within 200 feet of its waterbodies.

System Name	Impervious Area in 200ft buffer (acres)[1]	Total Impervious Area in Watershed (acres)	Total Watershed Area (acres)	% Impervious of Total Watershed Area	Impervious Area in 200ft buffer as Percentage of Total Watershed Impervious Area	MEP Total Unattenuated Watershed Impervious Load (kg/day)[2]	MEP Total Unattenuated Watershed Load (kg/day)	Impervious buffer 200ft WLA (kg/day)[3]	Buffer area WLA as percentage of MEP Total Unattenuated Watershed Load[4]
Swan Pond River	22.22	486.63	2,082.00	23.4%	4.6%	5.42	46.07	0.25	0.54%

1- The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated from GIS. Due to the soils and geology of Cape Cod it is unlikely that runoff would be channeled as a point source directly to a waterbody from areas more than 200 feet away. Some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of the wasteload allocation (WLA) it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody.
2- This includes the unattenuated nitrogen loads from wastewater from septic systems, fertilizer, runoff from both natural and impervious surfaces, atmospheric deposition to freshwater waterbodies and from the landfill.
3- The impervious watershed buffer area (acres) divided by total watershed impervious area (acres) then multiplied by total impervious watershed load (kg/day).
4- The impervious watershed buffer area WLA (kg/day) divided by the total watershed load (kg/day) then multiplied by 100.

Appendix C

Table C-1: Swan Pond River Estuarine System, Two Total Nitrogen TMDLs

Sub-embayment	Segment ID	Description	TMDL (kg N/day)
Swan Pond	MA96-111_2018	Dennis. (Determined to be impaired for nutrients during the development of this TMDL.)	**6.948**
Swan Pond River – North (Upper)			1.879
Swan Pond River- South (Lower)			4.271
Swan Pond River	MA96-14_2014	Headwaters, outlet Swan Pond, Dennis to confluence with Nantucket Sound, Dennis	**6.15**
Total for Swan Pond River Estuarine System			**13.098**